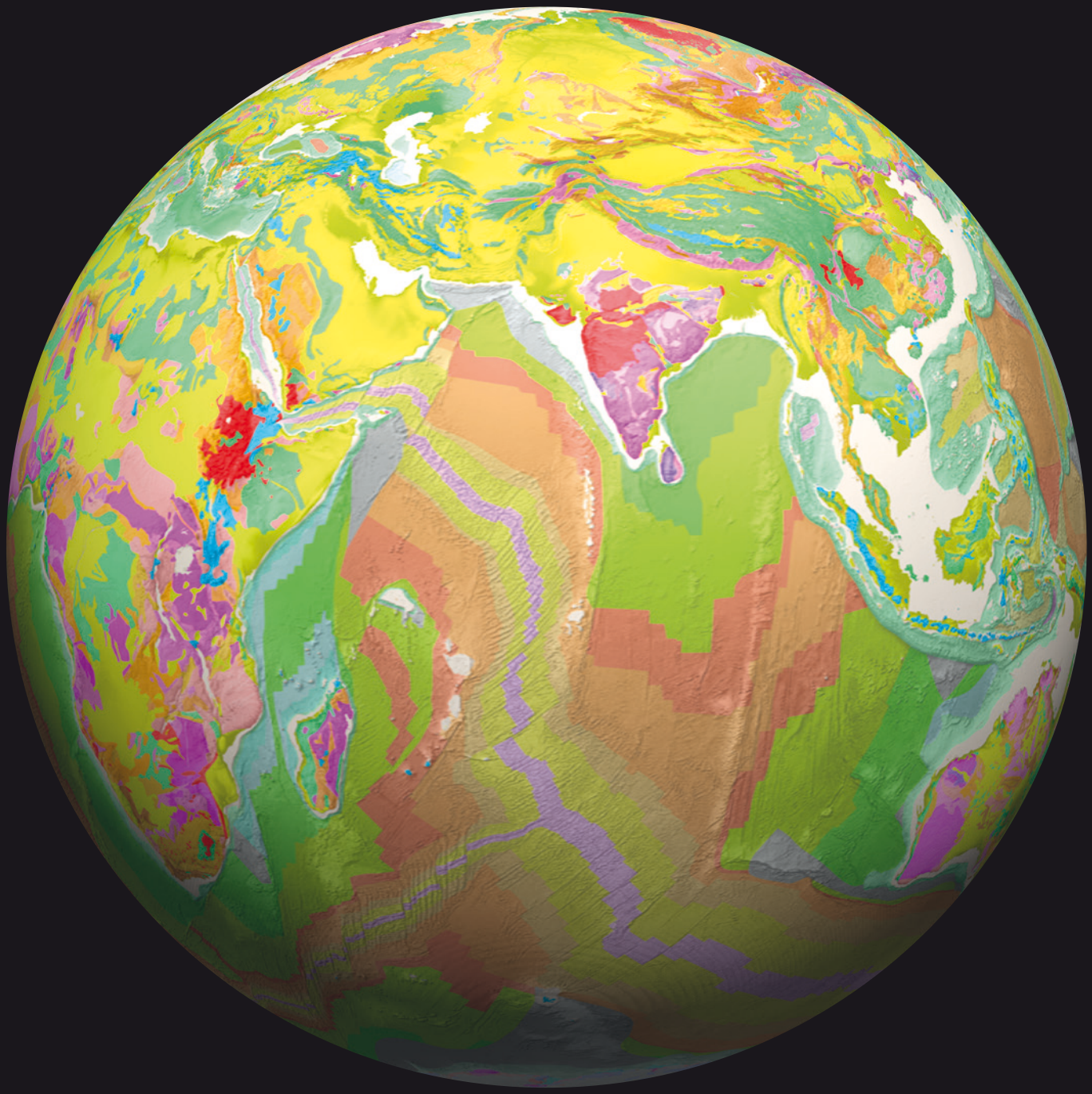
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

BGS Global Geoscience 2016–17

Geoscience for Sustainable Futures



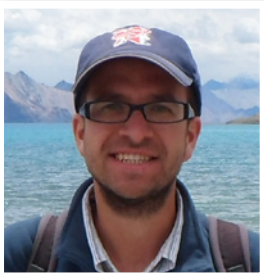
International work by the British Geological Survey

BGS Global Geoscience

Martin Smith, MBE
Science Director,
BGS Global Geoscience

Mike Ellis,
Head of Catchment Science
and Observatories

Keely Mills,
Environmental Scientist



J Gill,
International Development
Scientist

International work in BGS is entering a new and exciting phase of applied research. As part of the UK Governments initiative to increase investment on overseas development research a proportion of BGS – NERC funding has been re-aligned to focus on the UN 2015 Sustainable Development Goals (SDGs). BGS Global will now lead an integrated Overseas Development Assistance (ODA) programme worth £7.3 M over the next 3 years.

As a result, the BGS Global team is expanding and is now joined by Jo Mankelow, Diarmad Campbell, Colm Jordan, Keely Mills and Joel Gill; Mike Ellis will head up a new project on catchment science and observatories. Together, we will deliver an ambitious multi-topic programme across 13 countries and seek to attract GCRF and Newton funding to enhance the primary research aims.

Under the banner of *Geoscience for Sustainable Futures*, BGS will integrate our technologies and expertise into three interlinked research platforms each with a set of coherent objectives to explore the interfaces between human and earth sciences. The research will be co-designed and co-developed using participatory workshops to build sustainable networks of scientists, policy makers, NGOs, and communities in the identified countries. It will deliver not only research papers and new data but impact that makes a difference to lives and livelihoods. In order to understand and phrase the research questions partnerships are key and Memoranda of Understanding and research agreements have already been signed with various institutes and geological agencies in Kenya, Vietnam, India, Malaysia and island states in the Caribbean.

The BGS ODA programme builds on our extensive overseas experience and formally commenced in April 2017 with funding confirmed up to 2020. In the following pages examples of the types of project activities we will develop are described including, looking at the incidence of cancer in E Africa and potential links to soil chemistry, sub-urban planning for disaster resilient cities in SE Asia, geohazards in India, Malaysia and Ecuador and lakes and wetlands studies in China and Uganda.

In addition, informatics and management of data systems will also be a key element in the ODA programme. In in 2016 BGS delivered a new geology app for UAE and is currently trialling a volcanic app in the Caribbean. The BGS digital mapping system SIGMA is now widely used around the world and increasingly being customised to key sectors.

BGS is actively seeking partners across the wider research community and if you are interested in developing our understanding of human-earth systems then please get in touch.

In other project work, offshore BGS teams have been involved in mapping seabed geology and geohazards with ARUP in UAE and our deep water drilling rig has been in operation drilling black smokers on the Mid-Atlantic ridge and in part of an international research team investigating the Chixilub impact crater.

Finally, the Department for International Development (DFID) Investment Facility for Utilising UK Specialist Expertise (IFUSE) programme has been an important element of BGS Global activities in 2016. In West Africa, the DFID supported post-ebola programme in Liberia will finish in 2017 and in Sierra Leone deployments to the minerals and hydrocarbon sectors are opening up new opportunities. IFUSE deployments also took place in, South Africa for training in digital map production, in Morocco on digital capture and release of the national mapping dataset and in Tajikistan and the Kyrgyz Republic on capacity building in geodata and laboratory facilities in conjunction with the German and Finnish geological surveys.

Contact Martin Smith
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Front cover based upon World CGMW 1:50M Geological Units Onshore, with the permission of OneGeology.

BGS–SIGMA — global downloads exceed 3000!

BGS·SIGMA is a custom built, integrated toolkit for digital field data capture and data compilation. It has been designed and developed within the British Geological Survey and enables the assembly, capture, interrogation and visualisation of geological information as well as the delivery of digital products and services. At the end of September 2016 the BGS·SIGMA project team released the most recent version of the system, BGS·SIGMAv2015, as a free download on our website. (http://www.bgs.ac.uk/research/sigma/home.html)

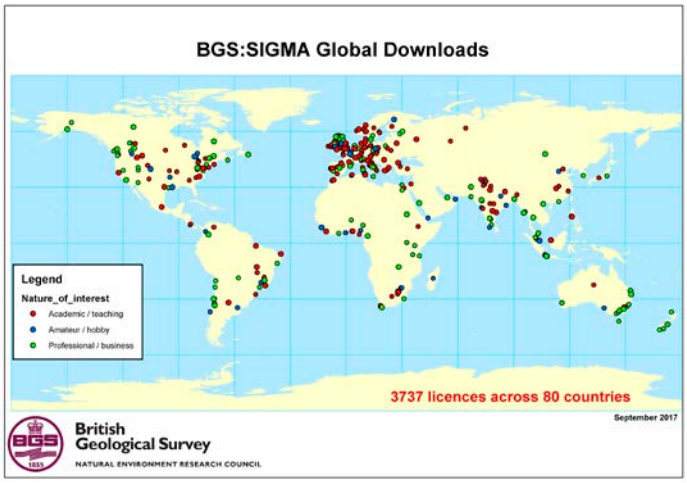
Within 2 weeks of release we had received nearly 300 licence requests, with that number rising week by week as users from across the world download the software. This means that since we first released the system in 2009 we have now issued over 3700 licences! Users range from universities, to mining companies to large overseas government departments and geological surveys and many have been using BGS·SIGMA for several years.

The BGS·SIGMAv2015 release was the culmination of 3 years work to upgrade the BGS·SIGMAv2012 system, improving the front end and providing extra functionality. BGS geologists have been using BGS·SIGMAv2015 for the capture of field data and to assist in data interpretation and compilation since April 2015.

BGS·SIGMA has evolved over the years. It was first developed purely with the intention of assisting our own BGS field mappers carry out their work in the digital world. As use of the system expanded, its potential for use in other areas of BGS became apparent, resulting in the system being extended to capture data for landslides, building stones and geodiversity. We soon discovered that there was interest in the system from outside the organisation and in 2009 we released the system externally. Since then BGS geologists have been using BGS·SIGMA for mapping, in conjunction with international geologists, in countries such as Madagascar, Tanzania, Singapore and the United Arab Emirates. We have provided training for geologists from many countries including Saudi Arabia, Liberia, South Africa, Norway and Chile, and have developed customised versions of the system for use by organisations across the globe including international mining companies. We also provide bespoke customisations for organisations outside the field of geosciences such as those responsible for heritage management.

For further information on the system or to discuss customisations we can provide for your project or organisation, please contact Nikki Smith (nasm@bgs.ac.uk), the BGS·SIGMA project leader.

Mapping with SIGMA kit in the Scottish Highlands.



Whether at the scale of a field, a village, a city, a country, or a continent, geology is fundamental to understanding human environment interactions and delivering the UN Sustainable Development Goals. The new BGS ODA programme Geoscience for Sustainable Futures (www.bgs.ac.uk/oda/) will for the first time, integrate BGS research on groundwater, soils, minerals, energy, urban planning, environmental modelling, and geohazards to deliver applied science that positively impacts on lives, livelihoods, and the natural environment.

The programme comprises three interlinked Research platforms (RPs) that will deliver interdisciplinary research, co-designed with in-country researchers, policy makers, NGOs and communities.

Contact: Principal Investigator:
Dr Martin Smith, Science Director, BGS Global
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RP1: Integrated resource management in Eastern Africa

Eastern Africa faces severe natural resource challenges due to exponential population growth, rapid urbanisation, and economic development. We will build on BGS's strong and diverse research experience in this region to underpin welfare and future economic growth by the responsible use of natural resources including:

i) quantifying how climate shocks and human stressors impact on water resources and identifying the appropriate water abstraction technologies and how these are governed to ensure they remain functional in the long term;
ii) enhancing the understanding of the mineral and energy resource potential in the region to facilitate informed policy development, support effective governance mechanisms, and aid inward investment; and
iii) using geological science to increase agricultural productivity and tackle micronutrient deficiencies by carrying out research linking bedrock geology and minerals to soil type thus informing decisions on improving soil quality, use of fertilisers, water retention, and plant nutrition ('hidden hunger') in vulnerable communities.

Contact: Dr Jo Mankelow
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RP2: Resilience of Asian cities

Many Indian and SE Asian cities are exposed to a 'perfect storm' of multiple natural hazards, an overwhelming pace of urbanisation and their resilience to environmental change unknown. Our objective is to build on our UK and past SE Asia experience to improve resilience by integrating geology in urban subsurface planning and urban-catchment science to:

i) demonstrate how the geological setting of the city and its wider catchment supports sustainable urban development;
ii) identify how and embed innovative use of data-informatics, sensor technologies, and modelling systems can improve urban planning;
(iii) determine the inter-dependencies between human and Earth systems in cities, and co-develop interventions that make city services more resilient appropriate to the geology of the city and its catchment.

Contact: Diarmad Campbell
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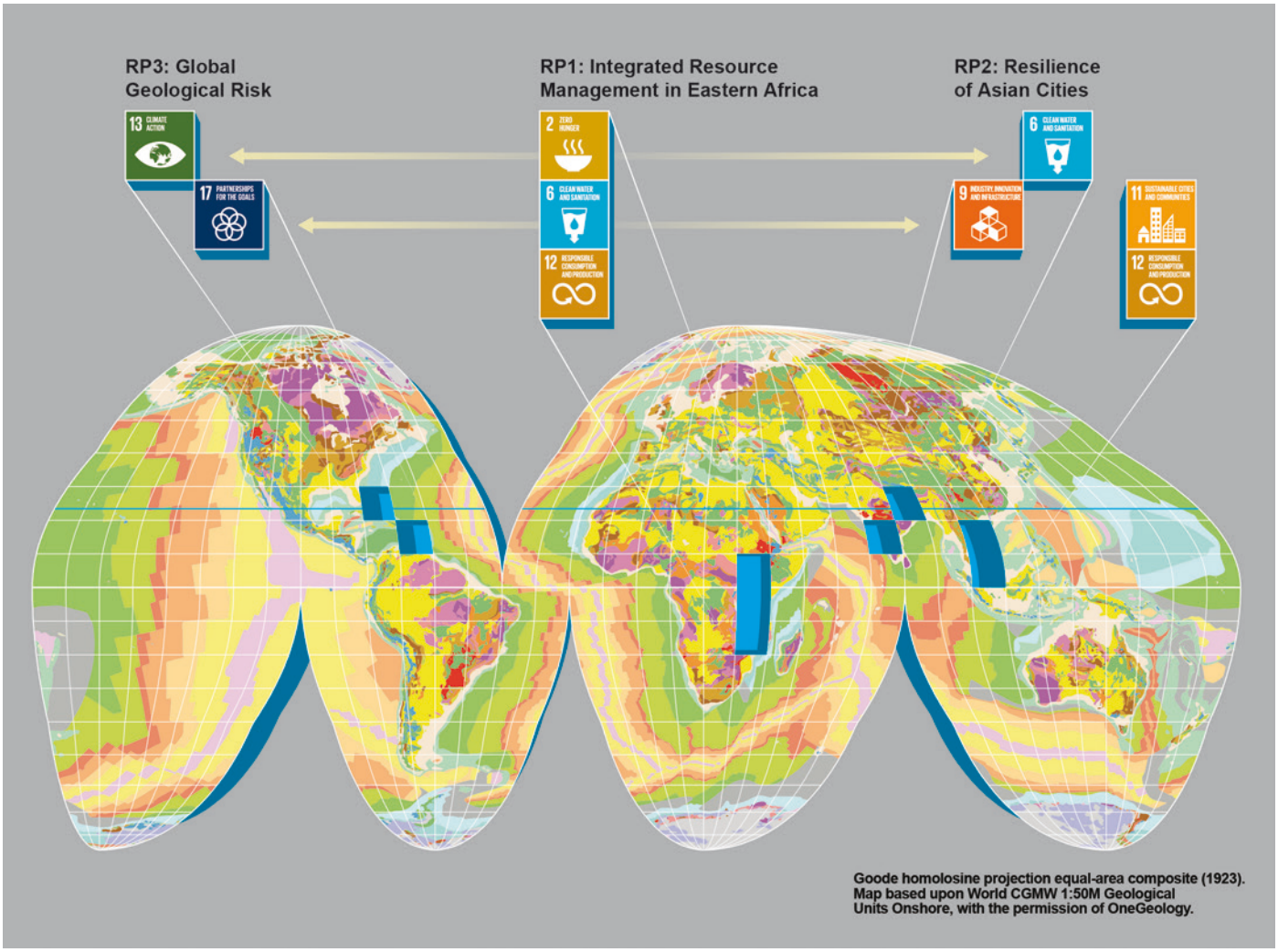
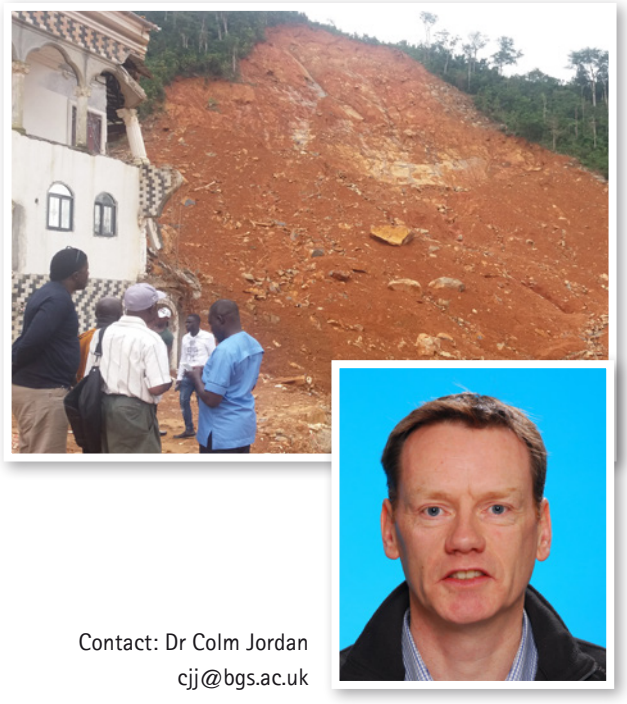


RP3: Global geological risk

Natural geological hazards and their associated risk including, volcanoes, earthquakes, and landslides, and their impacts, are of key concern to long-term economic growth. Focused on Latin America and the Caribbean, and the regions covered by the other platforms the objective is to characterise complex multi-hazard processes, and research the impacts of environmental shocks by:

i) advancing research into environmental processes and the interactions of multi-hazards (e.g., an earthquake triggering landslides);
ii) developing and utilising novel data collection, monitoring, and communication/visualisation techniques to improve disaster resilience; and
iii) building on our humanitarian assistance activities, and long-term planning experience to co-develop proactive systems to support NGOs, governments and mandated authorities when geohazards occur.



Contact: Dr Colm Jordan
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Tanzania and Kenya: environmental links to oesophageal cancer

Understanding why oesophageal cancer is localised within specific areas of the African Rift Valley.

Localised high incidences of oesophageal cancerare recordednear Mount Kilimanjaro (Tanzania) and in Kenya's Rift Valley, aroundEldoret. Many possible causal factors have been proposed, with one possibility being an environmental trigger.

To understand the relationship between environment and oesophageal cancer, the BGS InorganicGeochemistry team – supported by the Centre for Environmental Geochemistry and BGS Global – have partnered with theIARC-WHO and national partners in Tanzania (Kilimanjaro Christian Medical Centre) and Kenya (Moi University, University of Eldoret). Together we have designed and undertaken a detailed survey of soil, water and crop samples in both countries. These surveys aim to link geochemistry and crop data toenable a spatial understanding of the geochemistry (e.g., micronutrient composition,and the presence of potentially harmful elements) of differing climatic zones and food production areas in both regions. This researchwillinform future experimentation of agricultural methods to improve soil-crop transfer of micronutrients for onward health benefits.

Capacity buildingwas an important part of this programme, with training given to local university counterparts and public health workers from district offices. The partnerships demonstrate the value of cross-disciplinary collaboration between epidemiologists, health practitioners, biostatisticians, geochemists, farmers and local agricultural extension workers. Communities welcomed the research, andwere also important partners, providing useful local knowledge with respect to farming and health issues

Further reading

Blog Articles–Tanzania (http://britgeopeople.blogspot.co.uk/2015/03/is-there-environmental-link-to.html) and Kenya (http://britgeopeople.blogspot.co.uk/2016/03/geochemistry-and-health-in-kenyan-rift.html).

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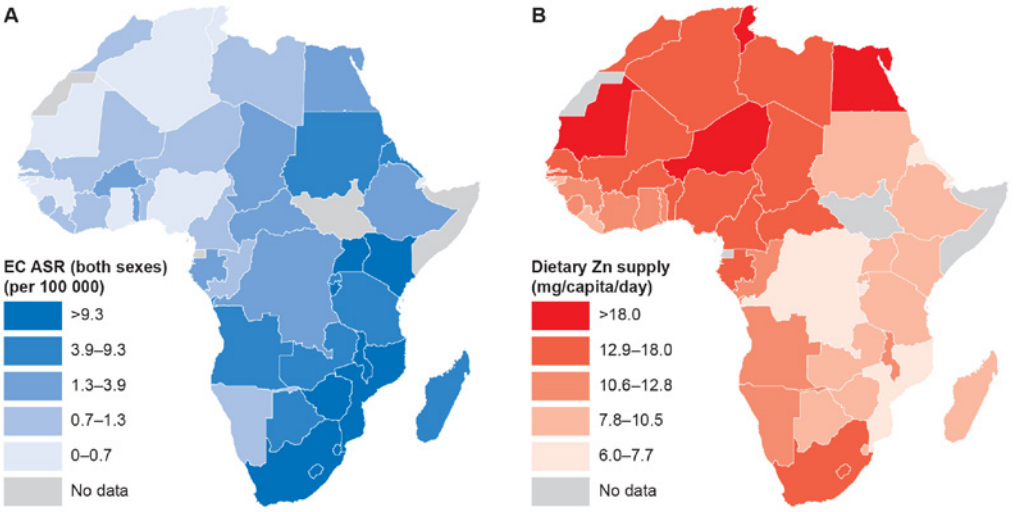
Collaborative working in the Kenyan Rift Valley.



A. age standardised rates of oesophageal cancer (GLOBCAN 2012) and B. dietry supply of zinc (joy et al. 2014.

Reconstructing animal populations in east Africa using sterol markers

A collaborative research project between Tufts University and Yale University (USA) and the Organic Geochemistry Lab at BGS, is using state-of the-art techniques in biogeochemistry to reconstruct long-term trends in animal populations in East Africa.

During the 21st century, animal populations in East Africa will be determined by climate change (primarily shifts in the amount, intensity, and seasonality of precipitation) and the balance between habit conservation and exploitation. In order to fully comprehend projected changes in these animal populations, there is a need to understand longer-term trends (100s to 1000s of years), and the natural response of animal populations to shifts in regional climate and recent anthropogenic disturbance.

This research uses a new methodology to reconstruct trends in animal populations using faecal sterol markers that are unique to groups of animals and that are preserved in sedimentary archives. Sterols are a class of organic molecules produced by plants (phytosterols) and animals (zoosterols), and are characterized and distinguished from one another by their chemical structure. Animals produce several different sterols,and whilst many of these common among species, the biochemistry of an animal's digestive tract and its diet produce a sterol signature that is unique to particular groups of animals.

Over hundreds and thousands of years, these largely insoluble zoosterols are readily deposited and preserved along with sediments in a variety of depositional environments (such as pools, lakes, and wetlands). Such sedimentary sequences are a natural archive, recording conditions in a watershed at the time of sediment deposition. If the composition of the animal population living in the watershed changed through time this is reflected in the composition of the faecal sterol markers preserved in the sediment. These temporal changes are a proxy for the composition of animal populations during regional climate change.

This research is funded by Tufts University (USA). If you would like to find out more about this project, or the capabilities within Organic Geochemistry at BGS, contact Chris Vane (chv@bgs.ac.uk)

African elephant dung.

Kuala Lumpur, Malaysia: forecasting local-level climate extremes and physical hazards

Recent disasters in Malaysia have revealed poor co-ordination and weak capacity in prediction of floods and landslides and there is concern over the occurrences of strong winds, air pollution (haze) and extreme temperatures.

Development of forecasting capacity is now important for major cities, particularly in view of climate change. Having secured funds from the Newton Fund, BGS is part of a consortium that will help forecast local level climate extremes and physical hazards in Kuala Lumpur.

BGS is working with lead-researchers from the University of Cambridge and the University of Malaysia, along with 14 other research and business organisations across the UK and Malaysia, including Meteorology Department of Malaysia and Department of Environment Malaysia. Working together the project team will customise climate and hazard models from the UK to forecast physical hazards common in Kuala Lumpur i.e. flash floods & floods, landslides, sinkholes, strong winds, urban heat and local air pollution.

To help deploy the modelling technologies and enhance local-level forecasting capacity the team will prototype a multi-hazard platform for managing and communicating risks increasing disaster resilience. The multi-hazard platform will be used by decision-makers in local government to assess short-term exposure to hazards and for long-term resilience assessments and city planning. The platform will also be used by the insurance sector to improve national insurance programmes.

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Mega city skyline.

India: resilient cities, Varanasi project

Situated on the banks of the River Ganges, Varanasi is one of the oldest continually inhabited cities in the world.

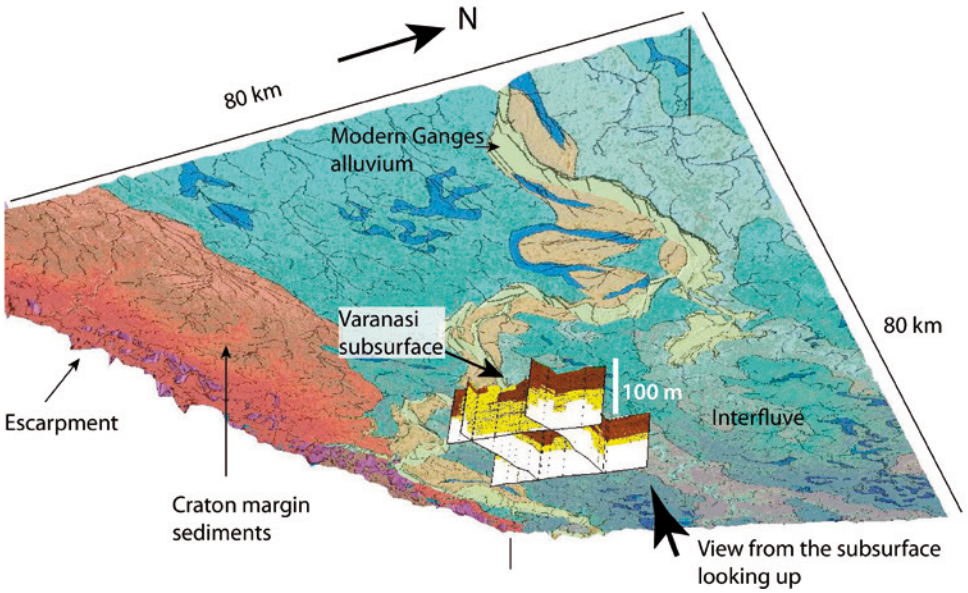
With significant cultural and religious importance its future sustainability is a priority in India, and it has recently been shortlisted as part of the country's Smart City Mission. However, like many cities on the mid-Gangetic Plain, Varanasi faces several challenges including: outdated infrastructure, severe surface water contamination, flooding, and uncertainty over the sustainability of heavily used groundwater resources.

To help address these challenges, UK Government (BEIS) funding has been

Varanasi waterfront and ghats.

provided to BGS to partner IIT Kharagpur in a co-funded programme of work to develop a geological framework for Varanasi. The main objectives of the work are:

- to carry out a city-scale borehole drilling programme in order to develop a 3D model of Varanasi's subsurface to underpin urban planning and infrastructure development.
- to understand contamination and recharge in the groundwater system under Varanasi.
- to improve understanding of how the river system is evolving in response to climatic and tectonic influences.



Modelling of sub-surface beneath Varanasi.

In February and March 2016, BGS staff joined IIT Kharagpur partners to undertake geological investigations, gather water well data, and collect samples of groundwater, sediment, and rock in and around Varanasi. The samples are now undergoing laboratory analyses. Over one hundred boreholes had been drilled by November 2016, and drawing on previous experience developing geological models for sustainable urban planning (e.g. Glasgow, Abu Dhabi, Singapore), BGS are now working with IIT Kharagpur to build a 3D subsurface model for Varanasi – as far as we are aware this will be the first for any Indian city.

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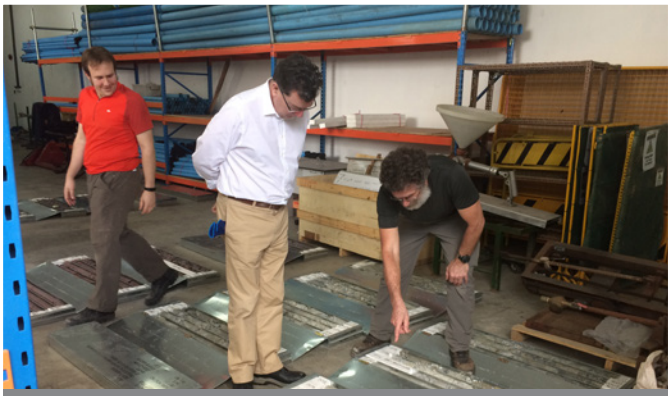
Typical street scene.

BGS: Singapore

The Republic of Singapore is a city state in SE Asia located approximately 100 miles north of the equator at the southern tip of Malay Peninsula. The main island, Pulau Ujong (Singapore Island), is only 50 km long and 25 km wide and yet supports a population of 5.4 million making it one of the most densely populated cities, and also countries, in the world.



Inspecting fresh sedimentary core.

Considered one of the region's major success stories over the past 50 years, Singapore has seen unprecedented economic and social growth, and is now considered to be one of the world's leaders in education, finance, shipping, electronic manufacturing, petroleum refining and tourism. Sustainable use of space is therefore vital for maintaining, and continuing, Singapore's unparalleled development. Competing land-use requirements at the surface, and an ever-growing population, has led Singapore to look to the subsurface to meet many of its future development needs. Ground beneath the surface is now considered an attractive development space for: energy production and infrastructure, waste disposal and treatment; groundwater abstraction and water storage; transportation infrastructure; industrial manufacturing and logistics; and scientific and military facilities. A comprehensive understanding of the geology is therefore critical to Singapore's continued prosperity and future development.

Gardens by the Bay.

In April 2016 BGS were engaged by the Geological Office of Singapore's Building and Construction Agency (BCA) to undertake a two-year multidisciplinary study that integrates core logging, geological fieldwork, seismic interpretation, laboratory testing and 3D modelling to resolve key unanswered questions about the geology of Singapore. An important component of the project is to refine the lithostratigraphical frame work of Singapore and update national and regional geological maps and models to ensure they can adequately facilitate future subsurface development. Knowledge transfer and training programmes will also help develop the future capacity of the BCA Geological Office to provide advice on geology to facilitate sustainable development in Singapore.

BGS have completed the logging of approximately 4 km of rock core extracted from boreholes drilled across Singapore Island and combined with detailed study of outcrops on Singapore Island and the surrounding, often much less developed, islands will help further refine the geological model. Fieldwork and core logging is expected to be complete by August 2017, and the final delivery of outputs including 3D models, maps and a new lithostratigraphical framework by March 2018.

Contact: Marcus Dobbs
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Ugandan Lakes

Many global organisations, governments, and scientists, are becoming increasingly concerned about the impacts of future changes in our climate, including the availability and quality of freshwater, especially with the targets recently set by the new Sustainable Development Goals in relation to access to clean water and sanitation for all.

This problem is of particular concern in areas such as East Africa, where changing climate, combined with increasing population pressure and associated deforestation and pollution, has caused changes in many freshwater ecosystems which provide drinking water for remote and vulnerable communities. It is anticipated that these climate and human impacts on freshwater systems, such as lakes, are likely to get worse in the future; tropical freshwater ecosystems are reaching a critical tipping point.

West Uganda is one of the most densely populated rural areas in sub-Saharan Africa (c. >500 people/km2), and population growth is placing unprecedented pressures on natural resources. In Uganda, freshwater lakes and their catchments play a crucial role in the livelihoods of many people, providing an array of services including aquaculture, agriculture, industry and ecotourism. In response to climatic and land-use changes, lakes are under threat from shifts in water balance, increased catchment soil erosion, high sedimentation rates and water pollution, impeding the provision of ecosystem services.

New research at BGS, (funded by the British Ecological Society) will quantify the onset and impact of human activity on lake ecosystem function and biodiversity in Uganda, in the context of a longer-term climate change perspective, by assessing the natural variability of lake ecosystems and determining their responses to 'natural' and anthropogenic-forced change.

Scientifically, there is a pressing need to understand the responsiveness of aquatic systems to the presence of humans, within a frame¬work of climate variability. Lakes, by their very nature are dynamic and responsive to changes in climate and land use; understanding this variability and resilience over long timescales is essential in the management of aquatic systems and the setting of water quality targets or defining limits of acceptable change.

This research will be undertaken by an international team of researchers, including: Dr Emilie Saulnier-Talbot (Université Laval), Dr Jackson Efitre (Makerere University, Uganda) and Dr Julius Lejju (Mbarara University Uganda).

Contact: Keely Mills
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With no potable water infrastructre, local communities travel long distances to obtain water for drinking and domestic use.

Sendai Framework for Disaster Risk Reduction 2015 - 2030

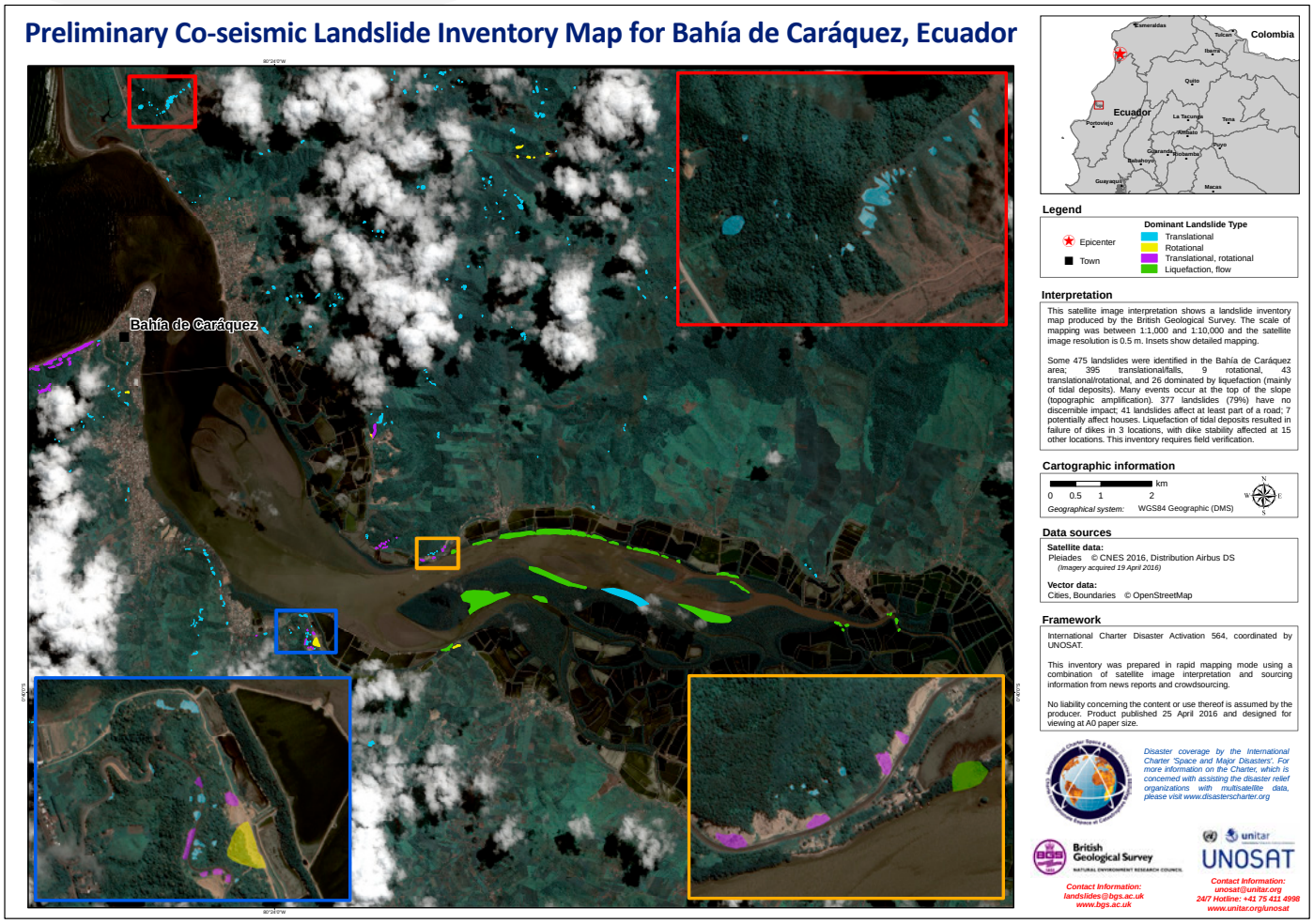
Ecuador: International charter for space and major disasters

When a geohazard event occurs (e.g., earthquake, tsunami, volcanic eruption, landslide) it can result in significant disruption to development progress. In addition to the fatalities and infrastructure damage portrayed in the media, disasters can threaten livelihoods, the immediate and long-term health of communities, and economic growth.

Reducing the risk and impact of disasters is therefore a strategic priority for sustainable development.

One method to reduce disaster impacts is to increase the capacity of nations to respond quickly and effectively after a disaster. The *International Charter for Space and Major Disasters* helps to link the requirements of disaster and relief organisations with satellite data captured over affected regions. For example, satellite imagery can be used to determine the extent of damage in remote hard-to-access communities, as well as in cities affected by disasters. The BGS is a project manager for some geohazard charter activations, supporting the interpretation of high-resolution satellite images. This information is communicated to groups such as government departments, civil protection agencies and disaster relief organisations.

Following the M7.8 Ecuador earthquake (16 April 2016), BGS contributed to the mapping of landslides triggered by the earthquake. BGS staff from the *Earth hazards and observatories* and *engineering geology* directorates collaborated



to acquire, process, and interpret satellite images provided through the *International Charter* and agencies such as UNOSAT. The team developed a set of inventory maps of landslides triggered by the 16 April 2016 earthquake in five different regions. BGS disseminated these inventory maps through the International Charter, UN Institute for Training and Research, various UK Government Departments and the NGO MapAction. These maps assisted relief efforts by showing how landslide debris affects populations, and blocks roads and rivers. Advice was also given to UK government via the Scientific Advisory Group for emergencies (SAGE), as well as to people on the ground assessing the situation. Similar work was done by the BGS after the M7.8 Gorkha earthquake in Nepal (25 April 2015) and the recent (August 2017) landslides in Freetown, Sierra Leone.

BGS support of the International Charter helps to address the UN Sustainable Development Goals through improving the capacity of nations to respond to natural hazards (Targets 1.5 and 11.5 respectively). This work also supports the *Sendai Framework for Disaster Risk Reduction*, including Priority 4 *'enhancing disaster preparedness for effective response and to 'build back better' in recovery, rehabilitation and reconstruction'*.

Recent landslide in Freetown, Sierra Leone.

Further reading and resources:

- International Charter: www.disasterscharter.org
- BGS and the International Charter: www.bgs.ac.uk/research/earthHazards/epom/InternationalCharter.html

Contact: Colm Jordan
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Sendai Framework for Disaster Risk Reduction 2015 - 2030

India: international research collaboration for landslide risk reduction in India

36 physical scientists, engineers and social scientists from nine organisations in the UK, Italy and India are collaborating to improve the assessment of landslide risk, early warning systems, and the preparedness of local communities likely to be affected by landslide hazards. This will help to protect lives, livelihoods, and the local economy of vulnerable landslide-prone communities in India and supports the priorities of the Sendai Framework for Disaster Risk Reduction (SFDRR).

Landslides affect a large area of India from the Himalayas in the north, the sub-Himalayan region in the north-east, the Western Ghats in the south and the Konkan Plains in the west. Triggered by intense rainfall, snow melt, earthquakes, they have a significant direct impact on development including dense settlement, particularly hill towns, National Highways, strategic trade corridors and UNESCO world heritage sites located in these fragile mountain terrains. Landslides can cause fatalities, destruction of property, damage to infrastructure and disruption of livelihoods and have a disproportionate effect on vulnerable sections of the communities in these areas.

With funding from the UK NERC/ DFID SHEAR (Science for Humanitarian Emergencies and Resilience) research programme. The LANDSLIP team is working to develop enhanced landslide risk assessment and monitoring methods in two study areas: the Darjeeling-East Sikkim districts in Eastern Himalayas, in the states of West Bengal and Sikkim and the Nilgiris District of the Western Ghats in the State of Tamil Nadu. The methodologies developed through this project will be replicable to the landslide-prone areas elsewhere in India (e.g. Uttarakhand) and South Asia.

The project consortium is jointly led by Dr Helen Reeves from the British Geological Survey (BGS) and Professor Bruce Malamud from King's College London (KCL) and includes partners from the Amrita University, Consiglio Nazionale delle Ricerche (Research Institute for Geo-Hydrological Protection), the Geological Survey of India (GSI), Newcastle University, UK Met Office, Practical Action Consulting India and Practical Action Consulting UK.

Dr Helen Reeves, Science Director for Engineering Geology, British Geological Survey said:

"I believe that LANDSLIP is providing a unique and exciting opportunity for UK, Italian and Indian scientists and engineers. It will provide new knowledge and information on landslide risk reduction in India and South Asia, supporting India's contribution to the Sendai Framework for Disaster Risk Reduction".

Dr Maneesha Sudheer, Director of Amrita University's Center for Wireless Networks and Applications said:

"In recent history there have been more landslides in Asia than in the rest of the world. Dramatic climate change is only making things worse. When you couple this with unregulated development, it can lead to significant loss of life and infrastructure. As such, multidisciplinary-approach programmes like LANDSLIP are urgently needed."

LANDSLIP is a 4-year project and was formally launched on Friday 20th January 2017 in New Delhi preliminary fieldwork has commenced and you can keep up with project developments at http://www.bgs.ac.uk/news/docs/Landslip_Press_Release.pdf.

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Landslide exposure in the highlands of Darjeeling, India.

Water quality risks to water supplies in Sierra Leone

During the recent Ebola outbreak in Sierra Leone BGS was commissioned by DFID to bring together and lead a team of experts to undertake a rapid desk study to assess microbiological water quality risks to drinking water sources in Sierra Leone.

The team included Dan Lapworth (BGS), Alan MacDonald (BGS), Richard Carter, an independent groundwater consultant and Steve Pedley, a public health specialist from the University of Surrey.

Although Ebola[1] virus is not a water-borne disease, care facilities for Ebola patients may become sources of outbreaks of other water-borne diseases spread through shallow groundwater from sources such as open defecation, latrines, waste dumps and burial sites which can contaminate water supplies. The focus of this rapid desk study was to assess the evidence for sub-surface transport of pathogens in the context of the hydrogeological and socio-economic environment of Sierra Leone. In particular, it investigated the robustness of the evidence for an effective single minimum distance for lateral spacing between hazard sources and water supply, and provides recommendations for protecting water supplies for care facilities as well as other private and public water supplies in this region[2].

The evidence gathered from this study were reported to DFID (Lapworth et al., 2015) and disseminated and used by the Government and NGO WASH community working in Sierra Leone during and after the Ebola outbreak.

Lapworth, D J, Carter, C, Pedley, S, and MacDonald, A M. (2015). Threats to groundwater supplies from contamination in Sierra Leone, with special reference to Ebola care facilities. *British Geological Survey Open Report*, OR/15/009. 87pp. [Open access via NORA: http://nora.nerc.ac.uk/510992/]

Contact: Dan Lapworth
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Kroo Bay slum in Freetown, Sierra Leone.

[1] The outbreak of Ebola virus disease in West Africa in 2014 is the worst single outbreak recorded. This outbreak has resulted in a large humanitarian effort to build new health care facilities, with associated water supplies.

[2] DFID circulated this report to various national and international agencies working in the WASH sector including WHO, UNICEF and CDC.

Morocco: IFUSE deployment

Morocco is well-endowed with natural resources including precious and base metals, phosphate and both onshore and offshore hydrocarbons.

The Moroccan government is keen to develop state-of-the-art digital services that will promote the country's natural resources to investors and to use geoscientific data services to exploit the educational and tourist potential afforded by Morocco's natural beauty and geological heritage.

In 2015 the Moroccan Ministère de l'Energie, des Mines, de l'Eau et de l'Environnement (MEMEE) published a 10-year 'future roadmap' that included a new national geological mapping programme, and development of a Geoportal for industry and the public that will feature a seamless national digital geological map.

BGS has a long history of work in Morocco, and we are currently working with the MEMEE to help develop the work programme and the skills base necessary to deliver its vision. In October 2015 three BGS staff spent 7 days with the MEMEE's Direction de la Géologie in the Moroccan capital Rabat. The visit was funded by the IFUSE scheme (Investment Facility for Utilising UK Specialist Expertise) which is funded by the UK Department for International Development (DFID). The scheme shares specialist expertise from across the UK government to support improvement of the business environment in DFID's partner countries.

During the deployment the existing digital and analogue data in the Direction de la Géologie were catalogued, and key staff interviewed to gain a picture of the organisational knowledge available and the skills-gaps to be filled. The available IT infrastructure including servers, networking, software and databases were also examined. The outcomes were a series of recommendations including construction of a secure and well-managed integrated data repository for existing and future data, and software, data resources, skill sets, procedures and techniques necessary to create the national digital geological map.

In May 2016 BGS presented our recommendations at the conference 'Journées Géologiques du Maroc', hosted by the Direction de la Géologie and a second IFUSE deployment took place in February 2017 which further refined the work plan and guided the Direction de la Géologie to begin drafting the formal standards and instructions that will underpin creation of the national map and Geoportal.

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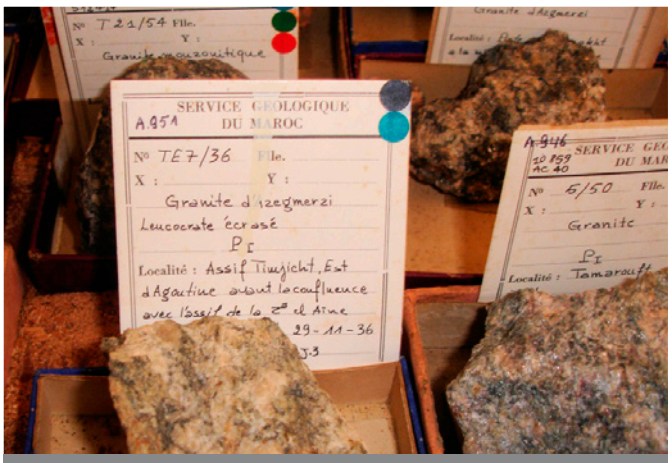
BGS staff with senior staff of the Moroccan Direction de la Géologie.



Specimens in the petrographic collection at the Direction de la Géologie.

IFUSE deployments in Sierra Leone

During 2016 and 2017, BGS staff were involved in several IFUSE deployments to Sierra Leone, as requested by DFID

BGS team with staff members from NMA and PD in Freetown.

In January 2016, Darren Jones carried out a short mission to Freetown which involved consultation with the Petroleum Directorate (PD), the National Minerals Agency (NMA) and a range of other stakeholders engaged in Sierra Leone's extractive industry.

Subsequently, DFID requested that BGS develop proposals for partnership working with these agencies. Kathryn Goodenough and Darren Jones visited Freetown in January-February 2017 to carry out a capacity review of the NMA and PD, and also to meet other stakeholders, including a World Bank mission who are planning for an Extractive Industries Technical Assistance project in Sierra Leone. This was followed in March by another deployment, which involved Darren Jones, Tim McCormick, Anubha Singh and Jane Robertson, and which focused on an assessment of the IT infrastructure and geo-data management at the NMA and PD.

The reports from these deployments led to a proposal for partnership working, which was supported by DFID. The partnership between BGS and the NMA and PD in Sierra Leone got underway on the 1st of April 2017, and will last for at least two years.

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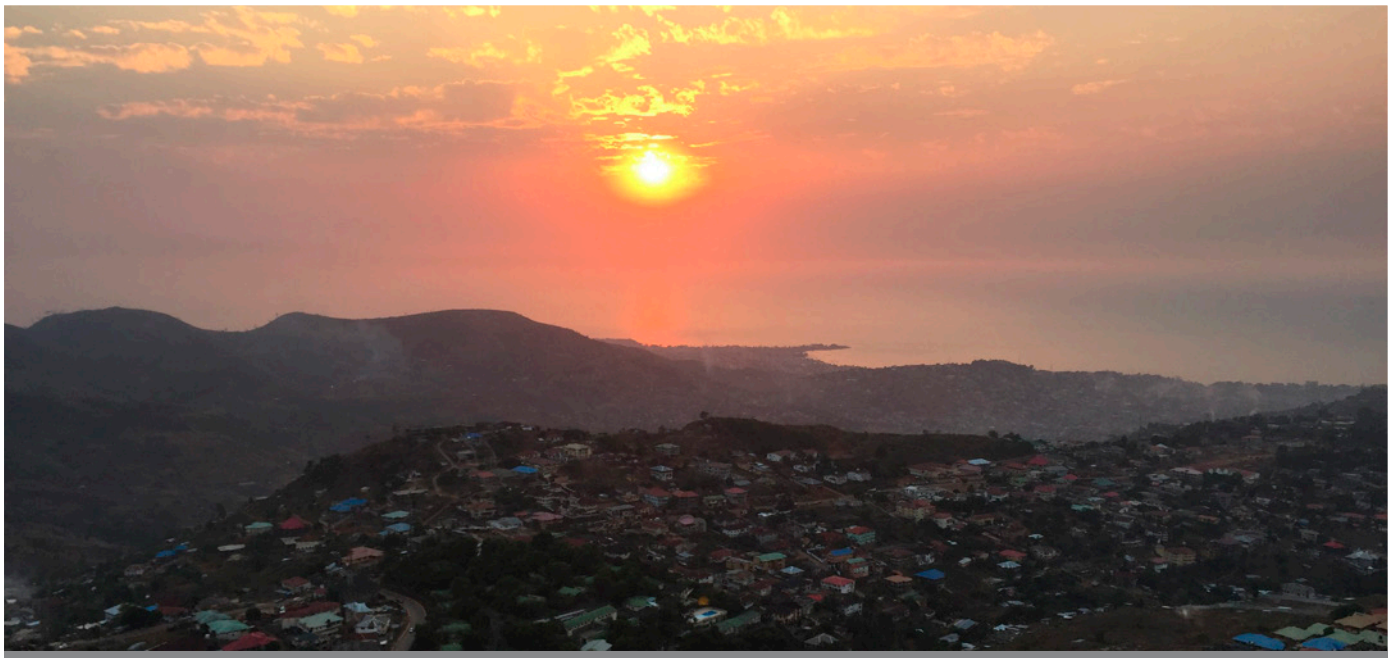

Sunset over Freetown.

JOINT RESEARCH WITH UON

Tasik Chini, Malaysia: quantifying and mitigating the impact of rapid development on vulnerable wetlands

Freshwater ecosystems in Malaysia are on the brink of collapse as a result of major industrial modification of their catchments; palm oil plantations, mining and hydrological modifications have altered the function of these vulnerable aquatic ecosystems, yet anthropogenic pressures continue to increase.

Lake sediment sampling in TasikChini.

When added to projected changes in water availability, the decline in water quality poses a major threat to regional sustainability, and has socio-economic implications for the local Orang Asli communities who are traditionally dependent on these wetlands. This research, in partnership with the University of Nottingham (UK and Malaysia), Universiti Kebangsaan Malaysia and the Tasik Chini Research Centre, is using a combination of contemporary monitoring and a palaeolimnological approach (analysis of sediment cores) to look at changes in the wetland flora, fauna and geochemistry through time. Using the longer-term perspective of a sediment records allows the definition of critical loads, and identification of system tipping points, as well as providing a benchmark of past conditions.

The resulting data will be used to identify the interaction and impact of multiple stressors, and the understanding of past conditions will provide targets for lake managers. With no regional expertise in palaeolimnology, this project will aid capacity training in the ASEAN region in the use of long-term wetland records for water quality management.

http://britgeopeople.blogspot.co.uk/2015/08/fieldwork-to-investigate-human-induced.html

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Typical Malaysian lake.

Project Hephaestus: the BGS digital mapping workflow in Chile

As part of a Newton funded project, run by the Satellite Applications Catapult, the BGS have been working with SERNAGEOMIN (The Chilean Geological Survey) and ENAMI (the national mining company) to trial the application of the BGS Digital Mapping Workflow to geological mapping in Chile.

SERNAGEOMIN and BGS staff using SIGMA.mobile to record field observations.

A recently mapped area in Chile was used as a study area to assess the value of the approach in this terrain.

SERNAGEOMIN are in the middle of a national 1:100 000 scale mapping programme. This programme initially focused on the well exposed north of the country; they are now extending the mapping in to the covered terrains (either by vegetation or modern deposits) to the south. They are therefore seeking technologies and methodologies to assist with the mapping in these areas.

This collaborative work focused on the use of high resolution satellite imagery and terrain models to enable pre-field geological interpretations to be made using GeoVisionary during the Virtual Field Reconnaissance stage of the project.

Four colleagues from SERNAGEOMIN and one colleague from ENAMI visited the BGS in October 2016 to undertake training in GeoVisionary and SIGMA. Following the training BGS staff worked with the Chileans to undertake Virtual Field Reconnaissance (VFR) interpretations for two study sites; Cerro Negro and El Trapiche in the Ovalle region of Chile.

Once the VFR interpretations were complete BGS staff travelled to Chile to assist SERNAGEOMIN and ENAMI with the ground truth fieldwork. VFR interpretations and the satellite derived base mapping were loaded to the tablet PC's and SIGMA.mobile was used to record field observations and any necessary alterations to the pre-field interpretations. Following fieldwork the BGS and SERNAGEOMIN split into two mixed teams to compile the new geological maps.

Virtual Field Reconnaissance using GeoVisionary in the BGS 3D room.

The BGS digital mapping workflow and associated tools were very well received by SERNAGEOMIN who have now adopted SIGMA and GeoVisionary and are continuing their use in different mapping areas.

During a separate trip, in late November, BGS staff visited SERNAGEOMIN to discuss the lessons we have learnt in the storage of borehole information, data models and structures and the generation of products derived from our data. These discussions were held over a week and the knowledge exchange workshops enabled the compilation of best practise documents.

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Indo-Gangetic Plain, India: developing new science to improve water-allocation decision making

The Indo-Gangetic Plain is unique, not only due to the sheer scale of the basin, but also as a result of its biophysical complexity and the dynamics of its socio-economic characteristics.

Partners at kick-off meeting in New Delhi.

This makes managing water resources in the region complex and challenging. Multiple stressors, including urban and agricultural intensification, unmanaged and inefficient water abstraction, and the huge demand on water by the energy sector, have altered the hydrology of the system; a fragile human-natural system imbalanced by water demand and seasonal water availability. BGS is part of a consortium, led by IIT Bombay and Imperial College London, who have secured funding from the NERC Newton-Bhabha Fund to improve the mapping and quantification of dominant interactions between people and the hydro-meteorological system of the Indo-Gangetic Plain. This research will develop new science to quantify the dynamic interface between environment and society to support improved decision-making on water allocation to secure food, water and ecosystem services.

This project will engage local communities to improve public understanding of water scarcity, empowering citizens to make water-related choices that improve their quality of life. The project also targets end-users in the private sector (water utility and energy sectors), and government departments (including water resources and public health) to provide policy-makers with improved integrated regional assessments of both water demand and availability enabling better planning for long-term water security.

Stay up to date on the project: https://www.researchgate.net/project/CHANSE-Coupled-Human-And-Natural-Systems-Environment-for-water-management-under-uncertainty-in-the-Indo-Gangetic-Plain

Follow CHANSE on twitter: https://twitter.com/chanseigp

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River Ganges.

Power station on the banks of the River Ganges, J O'Keeffe,Imperial College London.

British Geological Survey – Global Geoscience 2016–2017 20

International Ocean Discovery Program (IODP)

BGS leads a consortium under the name ECORD Science Operator (ESO), http://www.ecord.org/, to provide the expertise required to run drilling/coring expeditions as part of the International Ocean Discovery Program (IODP).

These skills and expertise include expedition planning, drilling/coring design, contracting, running offshore operations, management of the science party and science outputs, outreach, core curation, storage and sample management, all petrophysics measurements, downhole and core logging, running onshore science operations, logistics, outreach and education and associated budgets. Our partners include the universities of Bremen, Leicester and Montpellier.

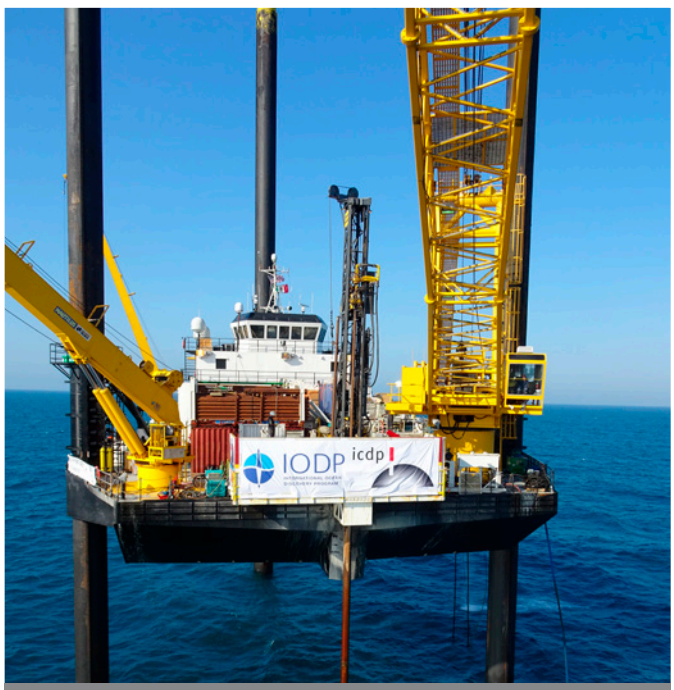
ESO specialises in undertaking complex projects where the water is too shallow for 'normal drill ships', there is ice cover, the sites are environmentally sensitive and require special operations, or there is complex shallow geology where it is possible to achieve better recovery in the near seabed zone.

IODP includes three drilling operators: the drill ship *Joides Resolution* is run by the United States and the riser drill ship *Chikyu* is run by Japan. ESO does not own a drilling platform, but contracts in drilling services specific for the diverse expeditions, from shallow water coring on the Great Barrier Reef to ice covered areas near the North Pole on the Lomonosov Ridge. ESO has used site investigation drill ships, an ice breaker modified to take a drilling rig, jack-ups and the UK research vessel the *James Cook* with two robotic seafloor drills.

The most recent Expedition 364 undertaken by ESO was to core into the 'peak rim' of the Chicxulub Impact Crater in 17 m of water to a depth of 1500 m below the sea floor (mbsf), some 30 km offshore of the Yucatan Peninsula in Mexico. The unique preserved nature of Chicxulub underneath 600 m of predominantly carbonate rocks has made this a top location for coring for many scientists since its discovery in the 1970s.

For 'Chicxulub' a bare liftboat or jack-up based in Louisiana was contracted with a drilling rig and fitted with drilling systems sourced from Salt Lake City, a series of ESO containerised laboratories and logging equipment from Europe, and vertical seismic profiling equipment from Canada. During mid-March 2016, this vessel was transformed into a drilling research platform, with a cantilevered drill rig over the bow and completed with core curation, geochemistry, micro/astrobiology, core scanning, general science laboratories, downhole logging, database, and management offices. Each laboratory was networked to a common sever system and linked to an ESO satellite broadband communications system.

This platform sailed around the Gulf of Mexico to Progresso, where the ESO and drilling teams joined, sailed to site and completed the final mobilisation. During April and May, this research drilling platform open holed (i.e. no core recovered) from seabed to 500 mbsf through the carbonates. The offshore science party then joined and from 500–1334 mbsf the borehole was continuously cored, passing through the Cretaceous-Paleocene boundary, through post impact Tsunamis deposits, breccia of increasing size and into the altered basement granites that had been crushed and moved +20 km during the impact. During the coring phase, 830 m of spectacular core with almost 100% recovery was collected. The operational phase was an outstanding success and the results



Caption coming . . .

have allowed numerical models of the asteroid impact to be refined as well as understanding how the rocks have been altered by the enormous energy imparted into the earth. Samples for geochemistry and micro/astrobiology and a comprehensive set of geophysical downhole logs and vertical seismic profiles were collected.

In early June, the drilling platform sailed back to Louisiana, and the equipment was removed. The core was first taken to Houston where it was CT scanned, before being transferred to Bremen, Germany, where 30 scientists from 11 countries joined the ESO team to undertake further core measurements, split, describe and sample the core.

The success of the operations was confirmed in September when the first paper in reporting the expedition results was published in 'Science' well before the12-month-post cruise moratorium period had expired. The new information obtained from the cores will re-shape the understanding of large impacts on the Earth and other planets.

Caption coming . . .

There was unprecedented media attention before, during and after the expedition. There were media days from the platform, real time educational links to schools, Reddit session and numerous interviews via satellite communications. A film crew that followed the offshore and onshore operation and several documentaries will be produced in 2017 including a BBC production. (http://www.bbc.co.uk/news/science_and_environment and search Chicxulub).

BGS, as part of ESO and the 'Mission Specific Platform' philosophy continually adapts to the diverse science requirements with new methods and equipment. BGS will continue to manage the science outputs for Chicxulub whilst building up the next expeditions to the Gulf of Corinth 2017 and back to Arctic coring on the Lomonosov Ridge in 2018. This expedition to an ice covered location will have a different set of requirements, including an icebreaker drillship and 2 support icebreakers and complex ice management methodology.

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Caption coming . . .

European Cost Action (TU1206) sub-urban — transforming relationships between geoscientists and urban decision-makers

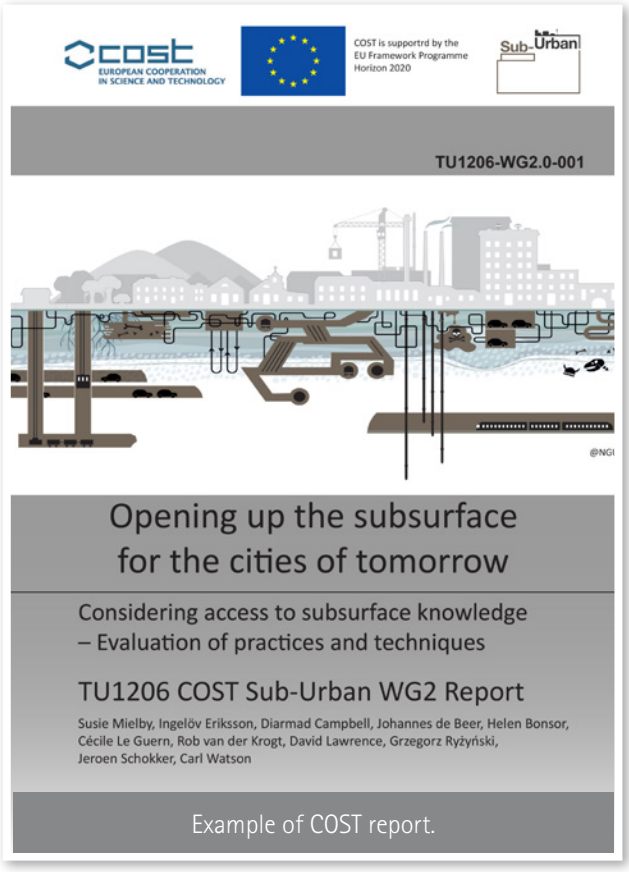
Cities worldwide are vital engines for economic growth and a focus for infrastructure development and investment (e.g. World Economic Forum, 2015). Europe's population is already substantially urbanised, and by 2050, UN-HABITAT (2012) estimates two-thirds of the global population will be too. Sustainable urban development is under pressure as a result. Better use of the subsurface can make a significant contribution to urban sustainability and resilience, but this needs both improved urban subsurface knowledge, and more effective communication of this knowledge to urban decision and policy makers. The BGS is leading a European COST Action SUB-URBAN (2013–17) to address both of these needs.

Urban geoscience is a key component of the current BGS strategy, *Gateway to the Earth*. This recognises the increasing pressure urbanisation is placing on space and resources. Hence, research and better understanding of the subsurface beneath cities must be a key focus for modern geological surveys. This research is necessarily broad ranging and interdisciplinary — the so-called *Science of Cities* (Government Office for Science 2016).

SUB-URBAN is a European Cooperation in Science and Technology (COST) Action (http://www.cost.eu/COST_Actions/tud/TU1206) intended to improve understanding and use of the ground beneath our cities. Led by the BGS, it stems from an initiative by the BGS and neighbouring Geological Survey Organisations (GSOs) in Northern Ireland, the Netherlands, Norway, Denmark, Ireland and Germany, to promote better knowledge and use of the urban subsurface. In this regard, the BGS's multidisciplinary CUSP project and strategic partnership with Glasgow City Council, have been particularly influential.

SUB-URBAN's key aim is to bring together, and so transform the relationships between, experts who develop urban subsurface geoscience knowledge — principally national GSOs (geological survey organisations), but also university researchers and others — and those who can most benefit from it. These are urban decision makers, planners, practitioners (private consultants and contractors), developers, and the wider research community. Operating under the EU Horizon2020 Framework Programme, and a Memorandum of Understanding now accepted by 31 countries, SUB-URBAN has established a broad transdisciplinary network of practitioners and city-partners (who provide key direction to the practitioners) across Europe, and to a limited extent, further afield.

Using a 'lighthouse and follower approach', city studies have been compiled, establishing typologies, and the current state-of-the-art in terms of urban sub-surface knowledge, planning and use in Europe. Specialist groups, two of which are led by the BGS, have also evaluated urban geoscience research, knowledge and good practice in sub-surface:



Example of COST report.

- planning
- data management
- 3D/4D geological and geotechnical characterisation and visualisation
- groundwater and geothermal monitoring and modelling
- geochemistry
- cultural heritage.

The reports are available on the Action's website (www.sub-urban.eu).

An online Toolbox will be released in March 2017, providing access to good practice, methodologies and guidance, with different entry points for practitioners, planners and policy makers, to help them:

- plan and manage uses of the subsurface
- protect subsurface ecosystem services on which cities depend
- recognise and address conflicting uses of the subsurface.

To achieve maximum effectiveness, SUB-URBAN encourages planning of urban areas that goes beyond spatial (2D) arrangement of surface and subsurface facilities and considers 3D (volumetric and depth zonation), and 4D (temporal) interactions between the built environment above and below ground, its supporting infrastructure, and multiple and co-existing uses of the subsurface. A BGS/NERC Knowledge Exchange (KE) Fellowship embedded within Glasgow City Council is pioneering this approach within the planning environment.

Existing city-scale 3D/4D model exemplars (e.g. Glasgow, Hamburg, Vienna, Basel), drawing on extensive digital ground investigation data, have been developed further to address groundwater, heat, lithology and engineering properties, and combined subsurface and above-ground (GeoCIM, BIMs) models are also in progress. These enable holistic urban planning, identification of subsurface opportunities, and cost saving by reducing uncertainty in ground conditions. KE between researchers and city partners has also supported new national exemplar-city projects (e.g. Oslo, Odense, Rotterdam, Lisbon, Bucharest).

At policy level, the Netherlands has pioneered legislation for mandatory consultation of, and contribution of data to, BRO, its subsurface key register. Alternatively, in Glasgow, free flow of subsurface data is encouraged on a voluntary basis by the BGS and Glasgow City Council through the ASK (Accessing Subsurface Knowledge) KE network. Such examples of good practice encourage others to follow suit across Europe, and globally. The BGS has opportunities to do so currently in Singapore (BGS Global Magazine, 2015) and soon in other Asian cities under the BGS ODA-NC programme (described in this issue).

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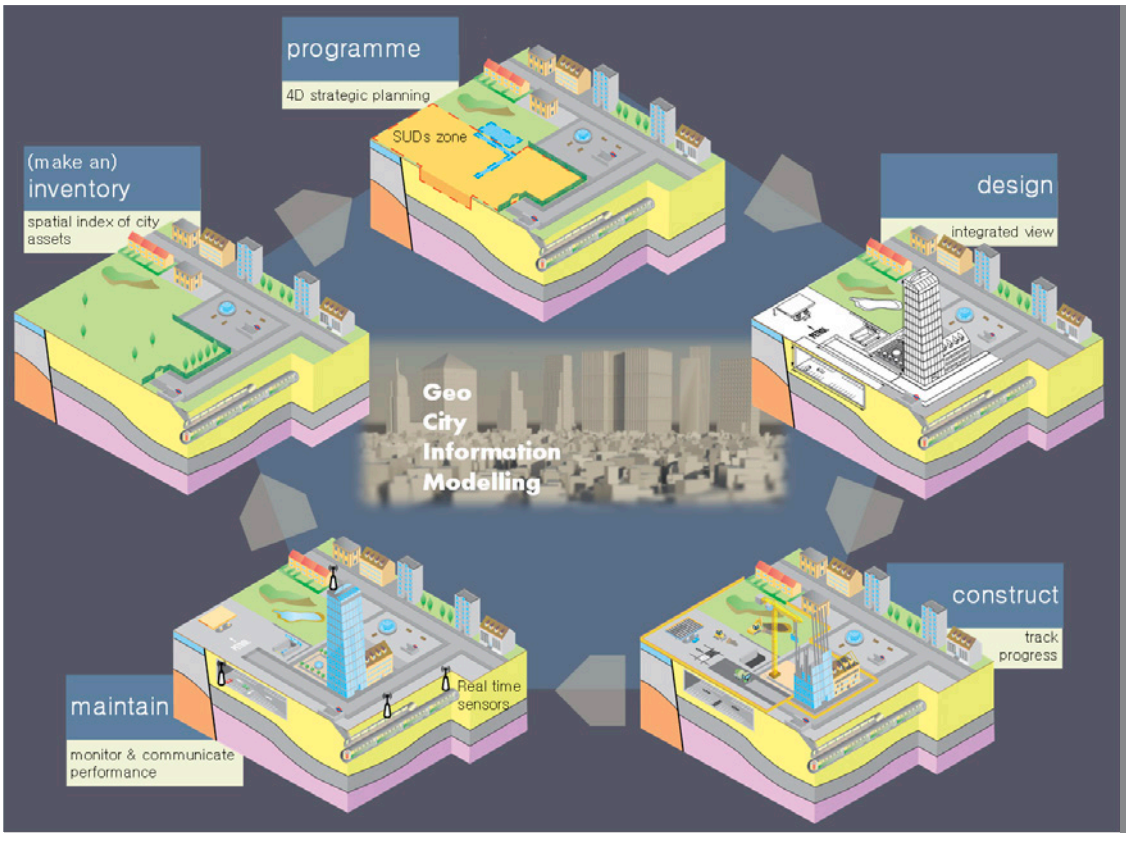

GeoCIM lifecycle, making all spatial data relevant to planning decisions available in a common data environment, supporting strategic planning and effective delivery of infrastructure projects by providing easy access to all related information at each stage of the process.

Partnership working

Memoranda of Understanding and agreements help facilitate working with overseas governments and are an essential framework to the planned technical and research programmes. BGS currently has c. 30 active MOU's with a wide range of partners around the world

In 2016-17 we signed agreements with, the Ministry of Energy in the United Arab Emirates, the General department for Geology and Minerals of Vietnam (GDGMV), the Vietnam Institute if Geosciences and Mineral Resources (VIGMR). The Indian Institute of Technology, Kharagpur, The Andhra Pradesh Capital Region Development Authority, the Addis Ababa University and Ministry of Agriculture, Ethiopia, and agencies in South Africa.

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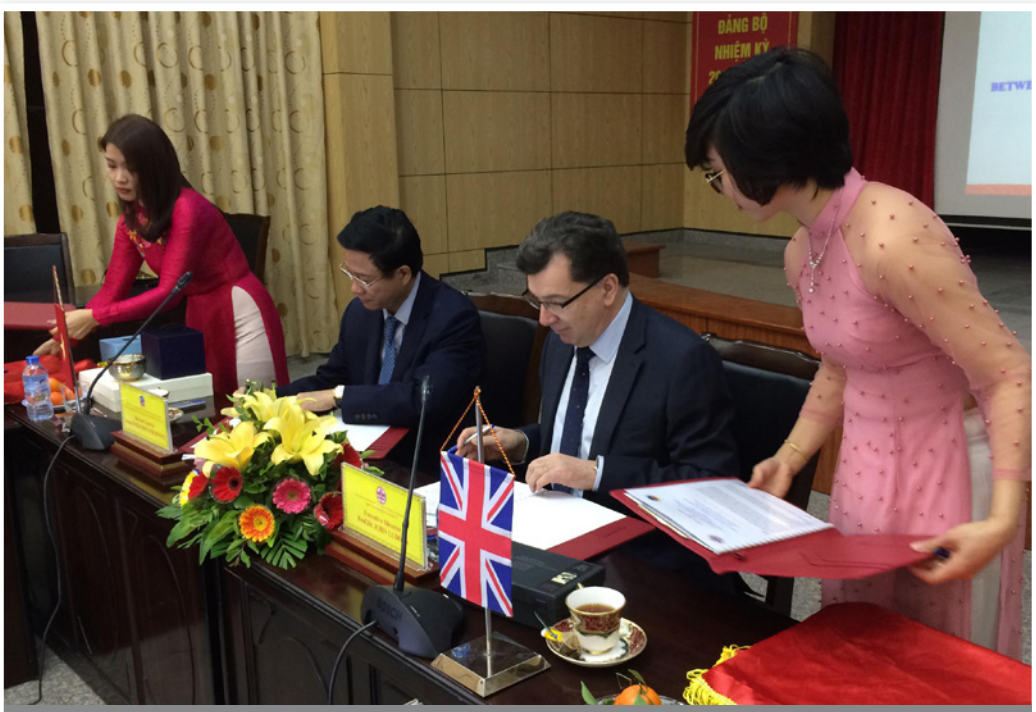

Prof. John Ludden,BGS Executive Director, signing MOU with Prof. Do Canh Duong, Director General of GDGMV.

Andrew McKenzie of BGS signing MOU with Sri Nara Chandrababu Naidu, Chief Minister of Andhra Pradesh and CRDA officials.

BGS current overseas grants at August 2017

Effective collaboration is key to international research BGS works extensively with a wide range of research partners both in the UK and overseas. The table below shows our current competitive won grant funded projects which are being undertaken/in collaboration with other countries. For further information please contact the named research lead via the BGS website.

Title	BGS lead researcher/ contributor	Funder/scheme	Countries engaged with the project	Project dates
Harnessing 'citizen science' to reinforce resilience to environmental disasters: creating and evidence based community of practive (CRRED)	Dr Anna Hicks and Dr Katy Mee	NERC/AHRC/ESRC – GCRF Building Resilience	Ecuador, the Caribbean and Nepal.	April 2017 - October 2017
GCRF: Strengthening Capacity in Environmental Physics, Hydrology and Statistics for Conservation Agriculture Research	Prof Murray Lark	RCUK – GCRF Growing Research Capability	Zimbabawe, Malawi and Zambia	October 2017 - March 2021
GeoNutrition – tackling hidden hunger in Sub-Saharan Africa	Prof Murray Lark	BBSRC/MRC/ESRC/AHRC/ NERC – GCRF Foundation Awards for Global Agriculture and Food Systems Research	Ethiopia	April 2017 - March 2019
A hidden crisis: unravelling current failures for future success in rural groundwater supply	Prof Alan MacDonald	NERC/DFID/ESRC – UPGro Consortium Grants	Malawi, Uganda and Ethiopia	April 2015 - April 2019
GroFutures: Groundwater Futures in Sub-Saharan Africa	Prof Alan MacDonald	NERC/DFID/ESRC – UPGro Consortium Grants	Sub-Saharan Africa (Ethiopia, Niger and Tanzania)	April 2015 - March 2019
Building understanding of climate variability into planning of groundwater supplies from low storage aquifers in Africa – Second Phase (BRAVE2)	Prof Alan MacDonald	NERC/DFID/ESRC – UPGro Consortium Grants	Burkino Faso and Ghana	April 2015 - March 2019

Integrating Hydro-Climate Science into Policy Decisions for Climate-Resilient Infrastructure and Livelihoods in East Africa (HyCRISTAL)	Daniel Lapworth and David MacDonald	NERC/DFID	Kenya and Uganda	April 2015 - March 2019
Probability and Uncertainty in Risk Estimation and Communication	Dr Susanne Sargeant	Newton Fund (NERC/ESRC/NSFC)	China	April 2016 - Jan 2019
Landslide Multi-Hazard Risk Assessment, Preparedness and Early Warning in South Asia: Integrating Meteorology, Landscape and Society	Dr Helen Reeves	NERC/DFID/ESRC (Science for Humanitarian Emergencies & Resilience (SHEAR))	India	November 2016 - October 2020
AGASTI – Upscaling Catchment Processes for Sustainable Water Management in Peninsular India	Daniel Lapworth	Newton Fund – NEWTON-Bhabha FUND	India	April 2016 - March 2019
CHANSES-India	Dr Christopher Jackson	Newton Fund – NEWTON-Bhabha FUND	India	April 2016 - March 2020
Disaster Resilient Cities: Forecasting local level climate extremes and physical hazards for Kuala Lumpur	Dr Helen Reeves	Newton Fund/Innovate UK – Malaysia UK Research and Innovation Bridges	Malaysia	Jan 2017 - October 2019
Monitoring the impact of the 2015/16 El Nino on rural water insecurity in Ethiopia: learning lessons for climate resilience.	Prof Alan MacDonald	NERC/DFID – El Nino Collaboration	Ethiopia	April 2016 - March 2018
Assessing human impacts on the Red River system, Vietnam, to enable sustainable management	Prof Melanie Leng	Newton Fund/RCUK (DIPI/TRF/NAFOSTED) – RCUK Newton-South East Asian Research Partnerships	Vietnam	April 2017 - March 2020
Marine E-Tech	Paul Lusty	NERC/EPSRC/Newton Fund	Brazil	July 2015 - July 2019
GEMex	Dr Christopher Rochelle	European Commission – Horizon 2020	Mexico	October 2016 - March 2020
Enhancing regional water security in semi-arid regions through improved metropolitan design (Workshop in Mexico)	Dr Andrew Barkwith	British Council and CONACyT	Mexico	November 2017
African Soil Geochem for Agriculture	Dr Michael Watts	Royal Society/DFID	Malawi	July 2015 - February 2020
Seismic monitoring after Italian earthquake of 24 August 2016	Dr Brian Baptie	NERC – Urgency Grant	Italy	August 2016 - March 2018

Other news in 2016–17

- Geologists, Andy Newall and Leanne Hughes delivered a workshop on BGS digital mapping and modelling to the Brunei government
- Mike Patterson, BGS's Head of Operations, attended the 52nd Annual Session of the Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP) in Bangkok and was a panellist on discussions on future opportunities and challenges for geology as part of the 50th anniversary of CCOP
- Geologist, Ed Hough presented BGS approach to reserve analysis at a CCOP sponsored shale gas workshop in Thailand
- Minerals and IT experts, Jo Mankelow, and Martin Nice visited Nairobi, Kenya to assist in establishment of the National Geoscience datacentre
- Martin Smith, BGS's Science Director for BGS Global presented at the Centenary Celebrations of the SerrvicoGeologicoCo-lombiano in June 2016
- Geologists, Jon Ford and Jon Lee continued with collaboration KIGAM delivering a workshop on urban mapping and modelling
- Petroleum and marine experts, Bob Gatliff and Margaret Stewart with British Council funding joined a UK FCO exploratory visit and a follow-up IFUSE funded mission with Kathryn Goodenough to Myanmar
- An IFUSE deployment to Central Asia (the Kyrgyz Republic and Tajikistan was carried out by GIS expert Nikki Smith and Martin Smith to asses data requirements leading to a new project

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NATURAL ENVIRONMENT RESEARCH COUNCIL